

A New Improved Method for Studying Reactions in Inverse Kinematics

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CONSIDERATIONS

- To interpret transfer reactions: (d,p) ($^3\text{He},d$) (α,t) ..., sensibly momentum matching is important: (usually 2-5 MeV/u above the Coulomb barrier).
- With inverse kinematics the **essential region** (where the DWBA approximations are valid and angular distributions make sense) **has low-energy particles spread out over a large solid angle.**

See some kinematics for $d(^{132}\text{Sn},p)$

What is needed?

- Good energy resolution (since energies are compressed), and good particle identification
- dE/dx measurements are difficult and time-of-flight may work best.
- Collecting particles from $\sim 2\pi$ (a hemisphere) onto a relatively small detector.

With a **Si ball** the detection of low-energy particles is difficult, particularly in a sea of high-energy ones.

A **Magnetic spectrograph** would have trouble approaching the 2π solid-angle by ~ 2 orders of magnitude.

POSSIBLE DEVICE

- A uniform-field, large-bore solenoid that brings particles below a certain momentum to the axis, where a detector is located.
- The length of the detector on the axis determines the fractional momentum bite.
- Angle information (needed to $<1^\circ$) can be provided from a combination of energy, and position along axis
- The detector itself could be thin, cooled Si which should yield good energy and t.o.f. resolution.
- Segmentation along the axis need not be great - perhaps 20 segments if a factor of two in momentum is covered.

For example, for $d(^{132}\text{Sn}, p)$

Proton energy range 1 - 8 MeV

Corresponding to lab angles of 180° - 100°

Solenoid ($r=25$ cm) ~ 3 T

Detector length ~ 25 cm

Detector segmentation ≤ 1 cm

Time of flight ~ 8 - 25 ns

Cyclotron Period for Various Particles ($B = 2T$)

Particle	$T_{\text{cyclotron}}$ (ns)
p	32.8
d, α	65.6
t	98.4
^3He	49.2

$$T_{\text{cyclotron}} = \frac{2\pi m}{qB}$$

$T_{\text{cyclotron}}$ is independent of energy
and angle!

Assume a stationary source in a solenoid.

The particles with energy E will return to the axis at a distance z from the axis:

$$z = \tau v_z$$

$$\tau \equiv \frac{2\pi}{\omega_{cycl}}, v_z \equiv \sqrt{\frac{2E}{m}} \cos(\vartheta)$$

where θ is the angle of emission with respect to the solenoid and E and m are the kinetic energy and mass of the particles.

Advantages of a Solenoid

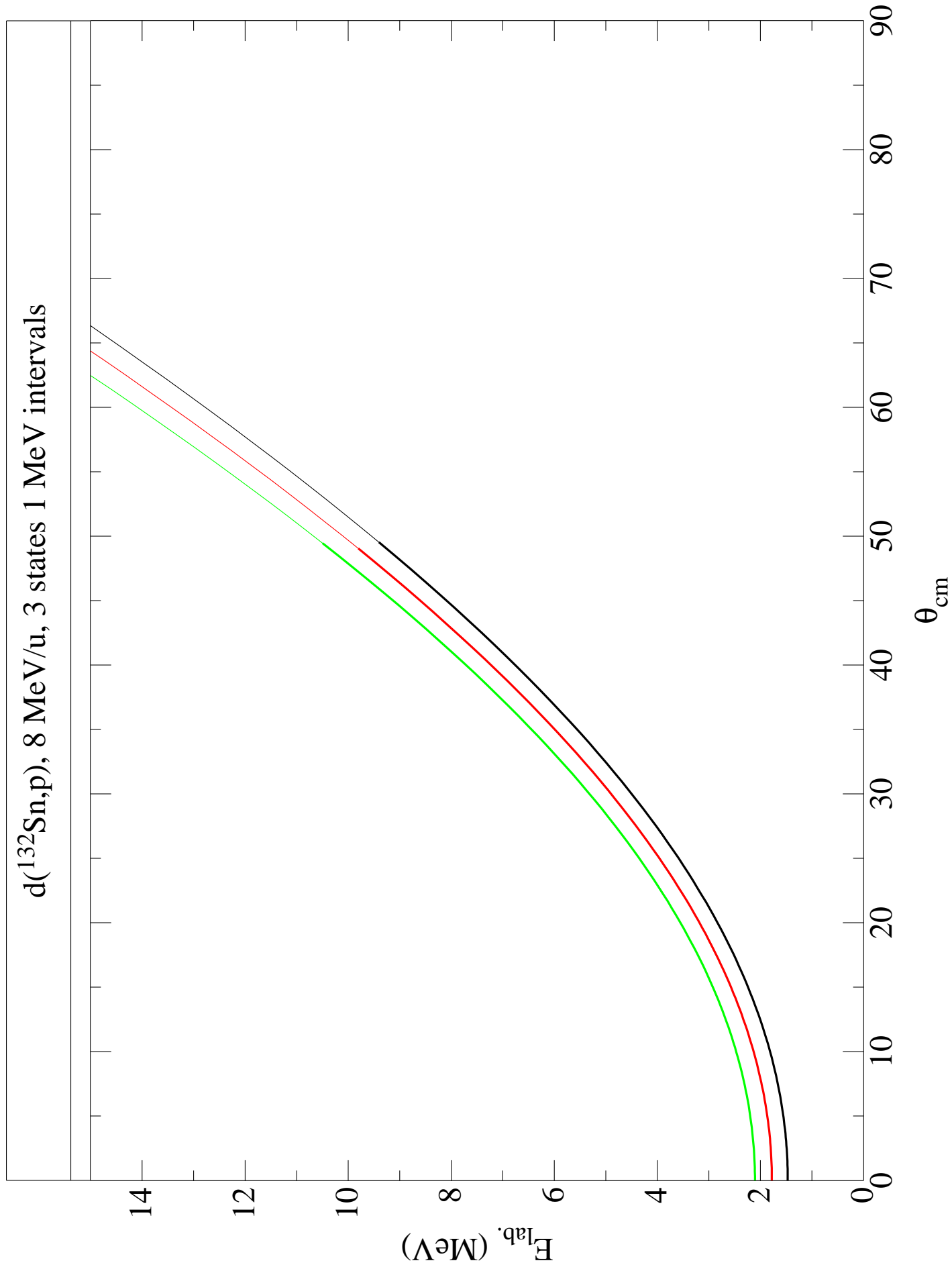
Over a large 2π array

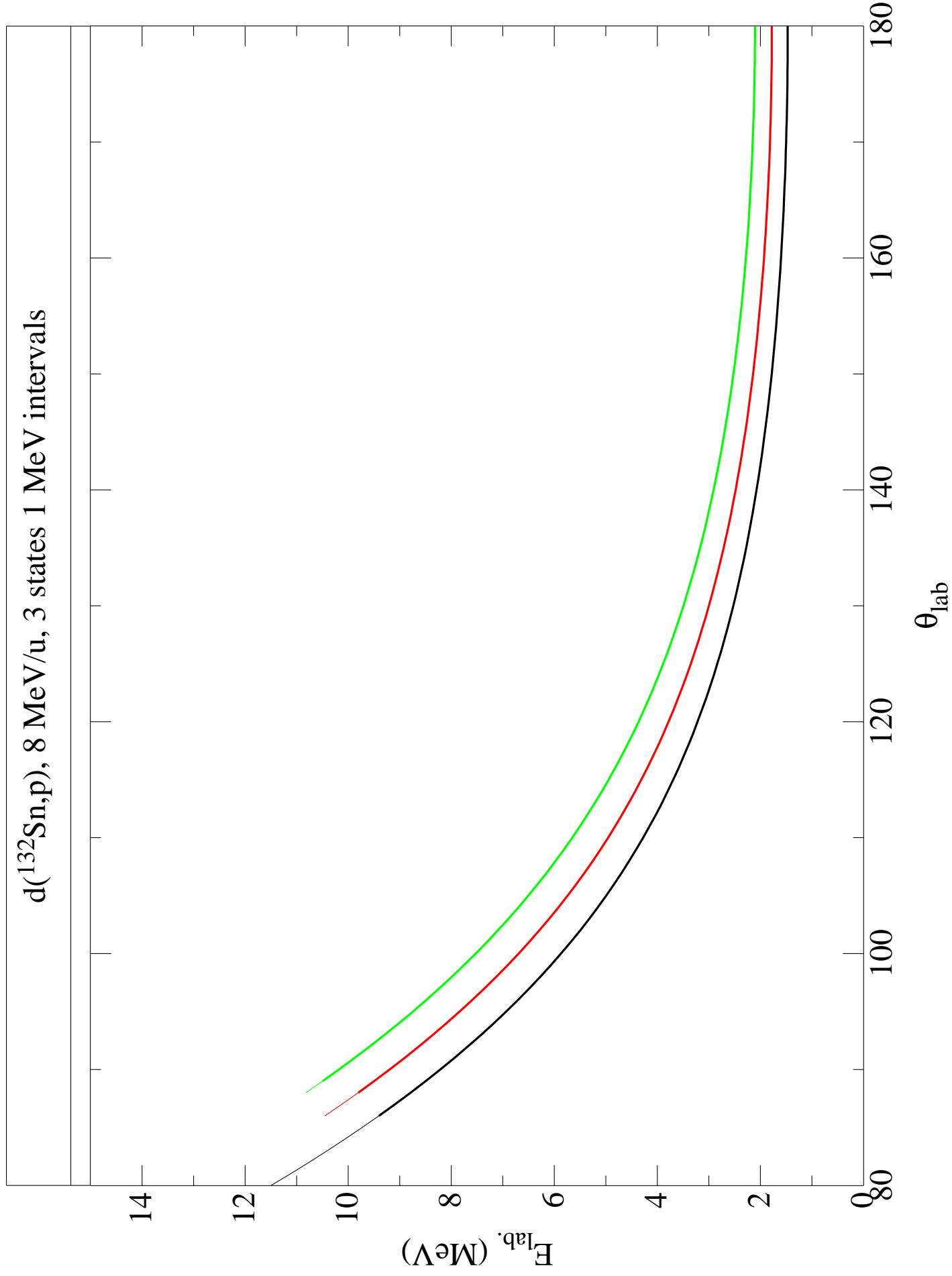
- **Energy resolution:** better by a factor of 10-20 because of magnetic properties.
- **Particle ID:** simple and clean with TOF (rather than dE/dx , that needs a second large layer of Si detectors).
- **More compact & simpler detector:** Detector area $\leq 200 \text{ cm}^2$, rather than $\geq 3000 \text{ cm}^2$; at least an order of magnitude fewer channels of electronics.

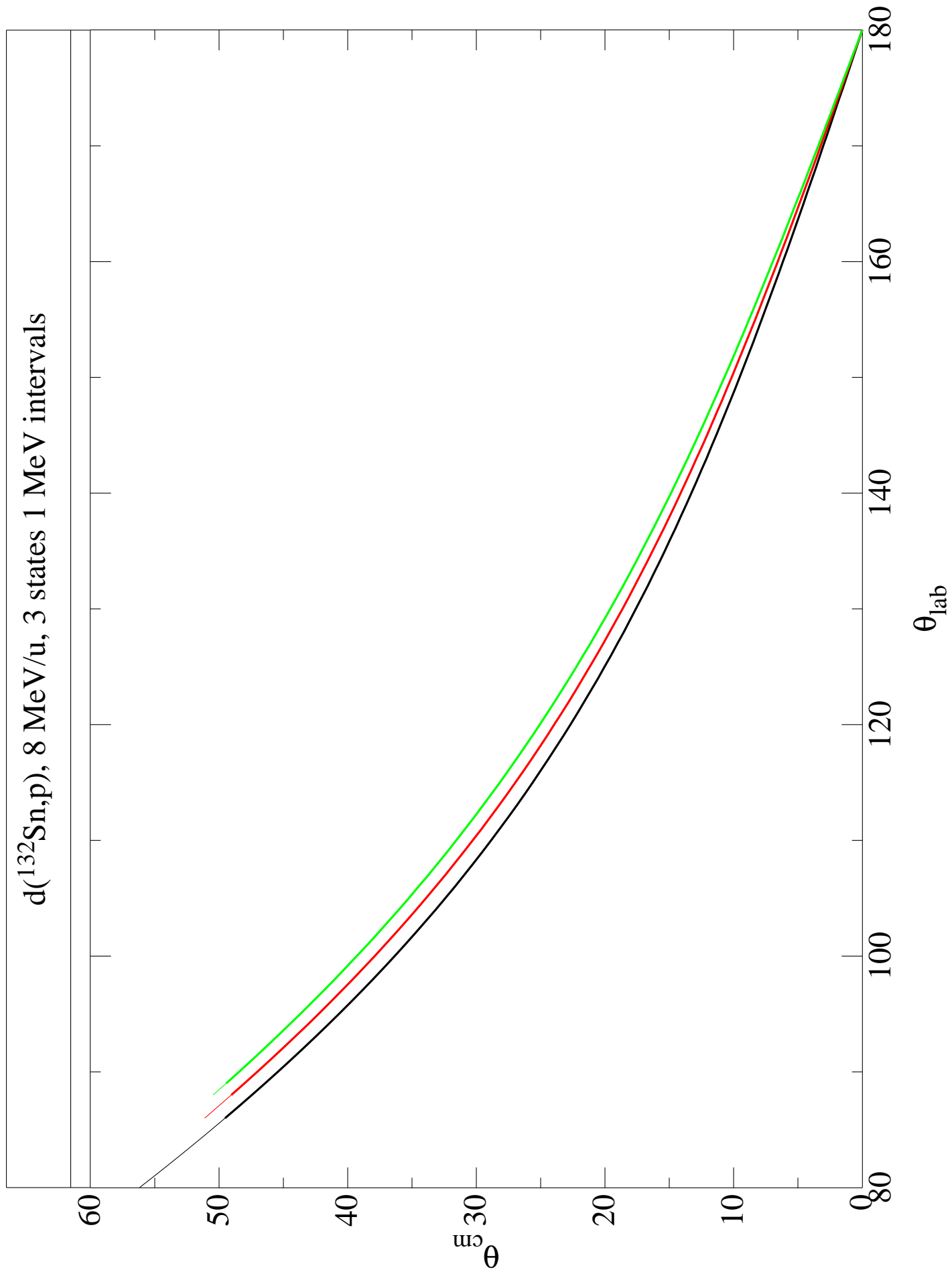
Disadvantage:

Need **\$1M:**

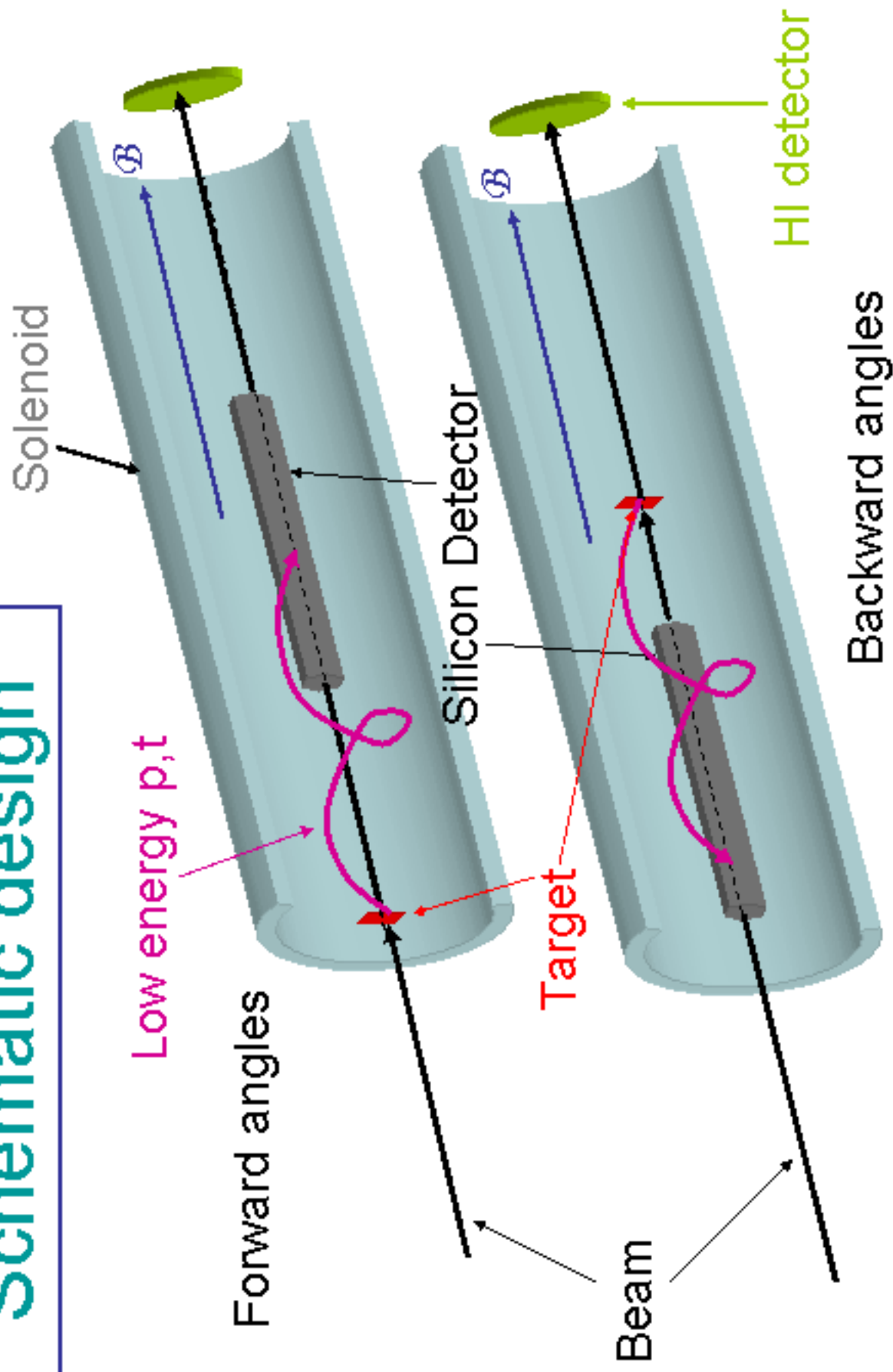
Superconducting Solenoid: $B > 2 \text{ T}$, $L \approx 1 \text{ m}$, Large bore ($> 0.5 \text{ m}$), uniform field over volume ($< \text{few } \%$), similar to MRI magnets.

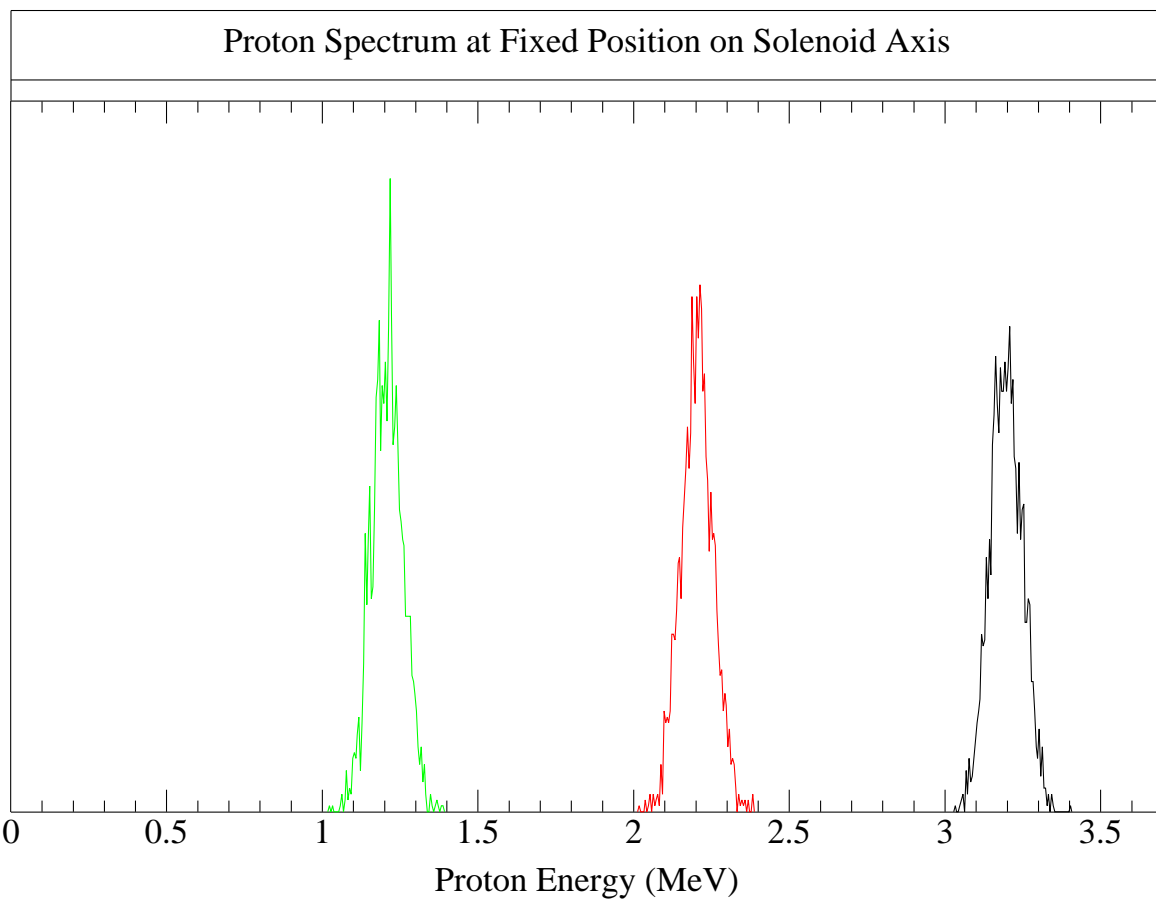
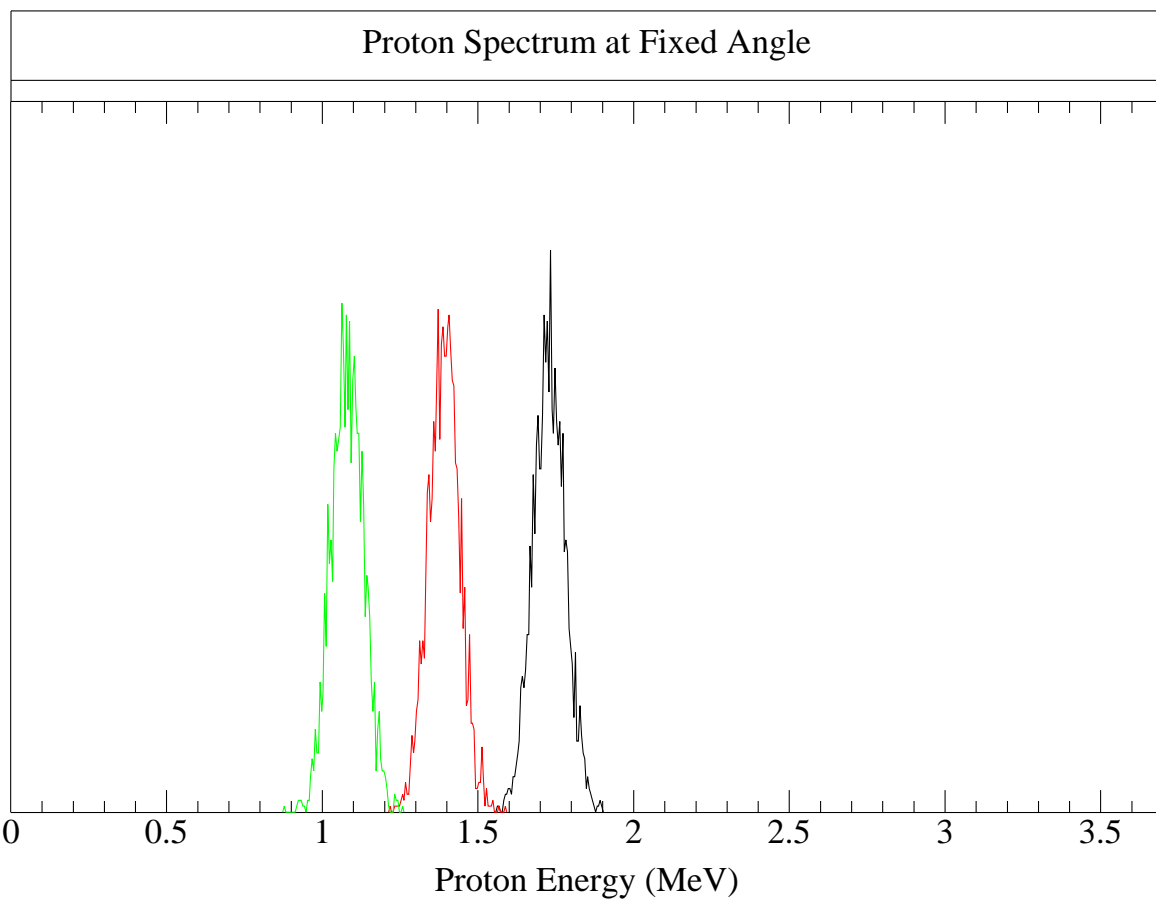


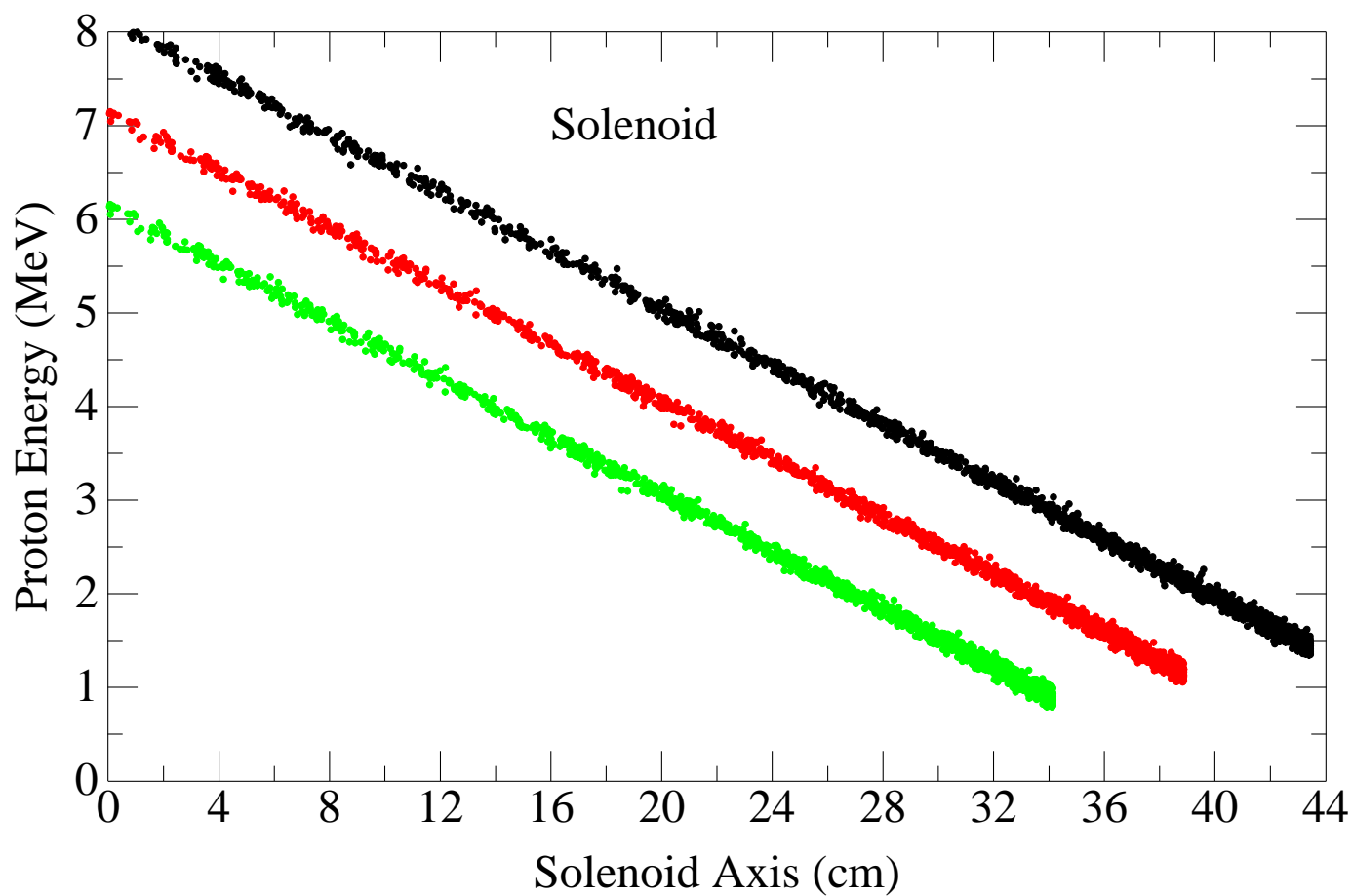
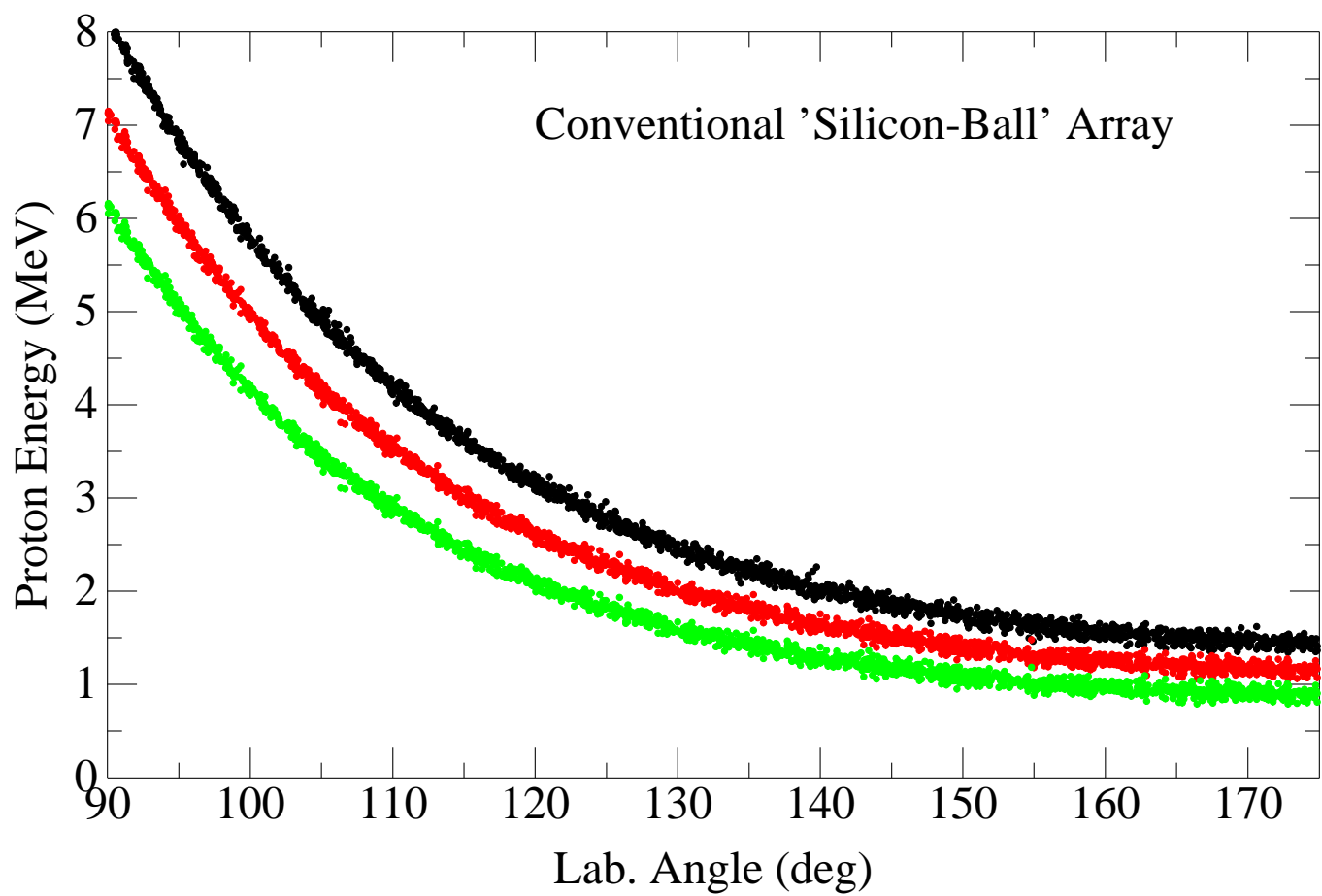




Schematic design







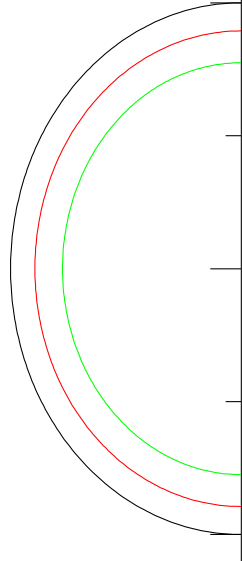
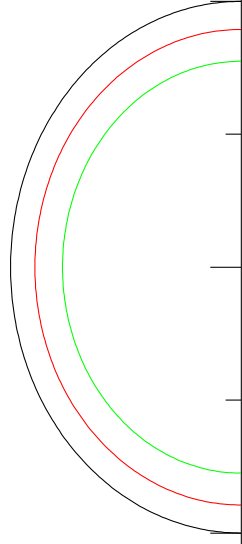
Distribution of Particles on Axis of Solenoid

Recoil velocity



Stationary Source

Recoiling Source



-10

0

10

20

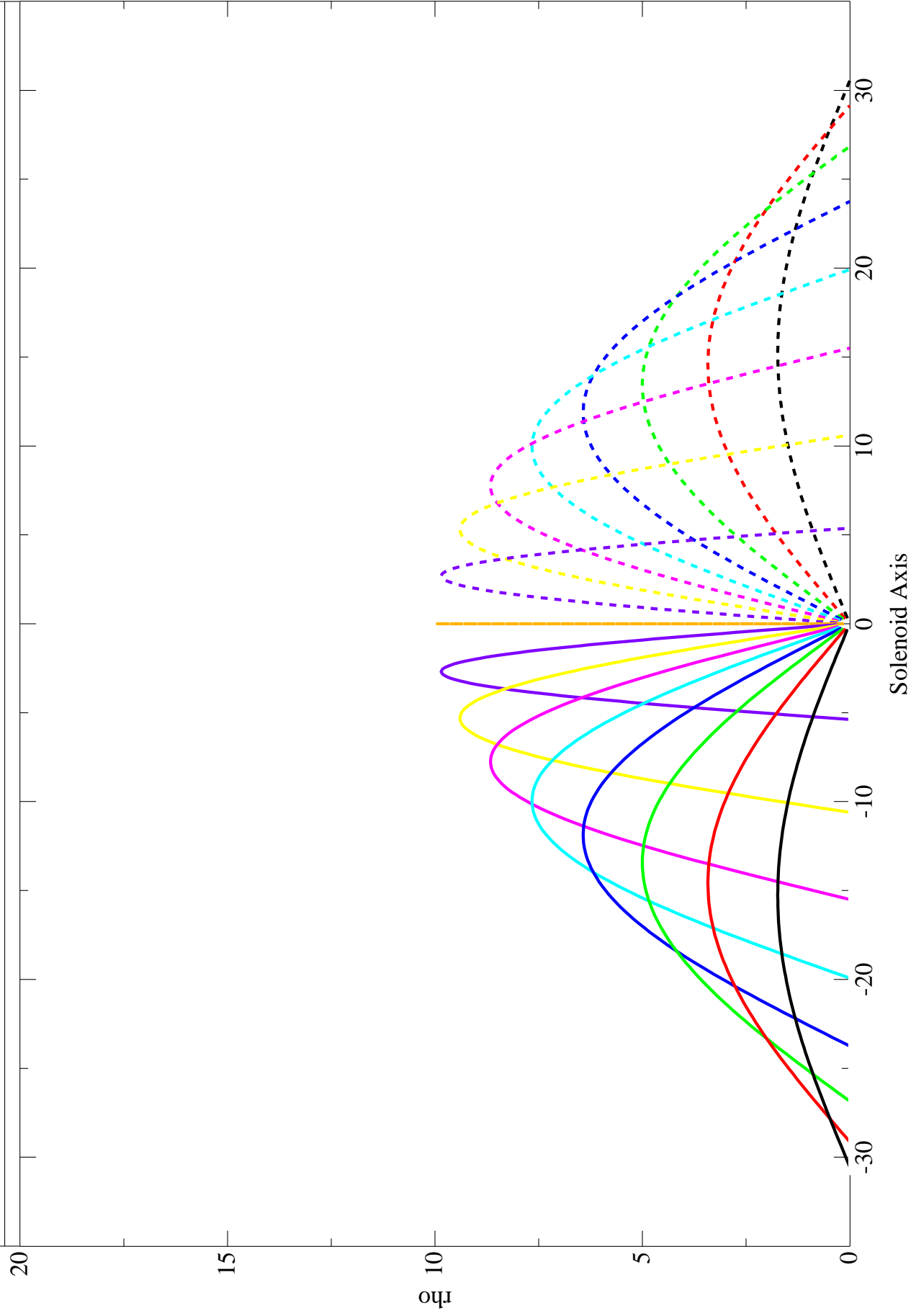
30

40

50

Solenoid Axis

Trajectories in a solenoid for stationary source



Trajectories in a solenoid for moving source

